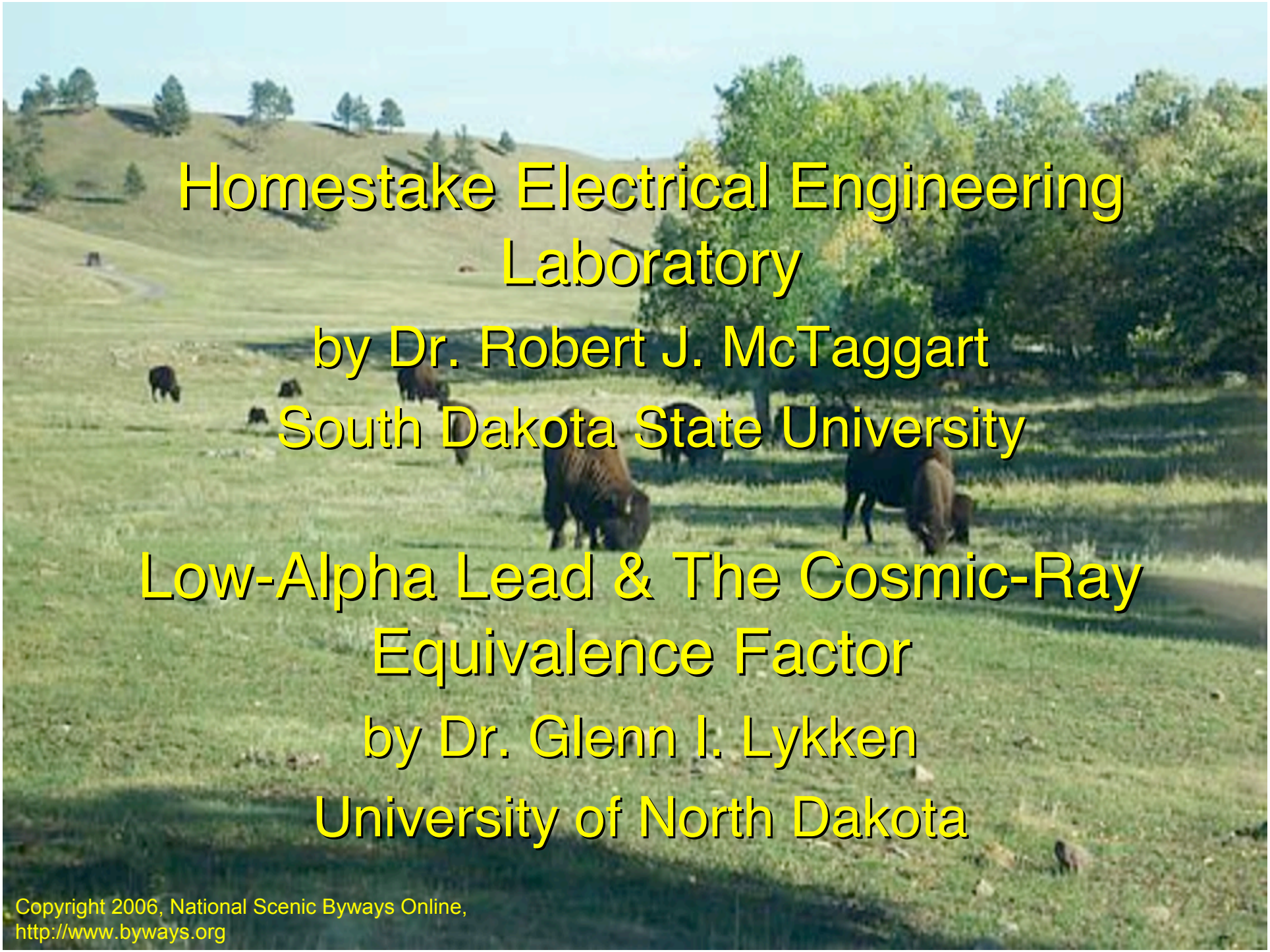


Homestake Electrical Engineering Laboratory

Homestake Mine: Lead, SD

February 9-11, 2006

Dr. Robert J. McTaggart

South Dakota State University

- Dr. Robert J. McTaggart

  Assistant Professor of Physics
- Dr. Michael Ropp

  Associate Professor of Electrical Engineering
- Kevin Dalsted, Associate Director

  South Dakota Space Grant Consortium

South Dakota School of Mines and Technology

- Dr. Li Chen

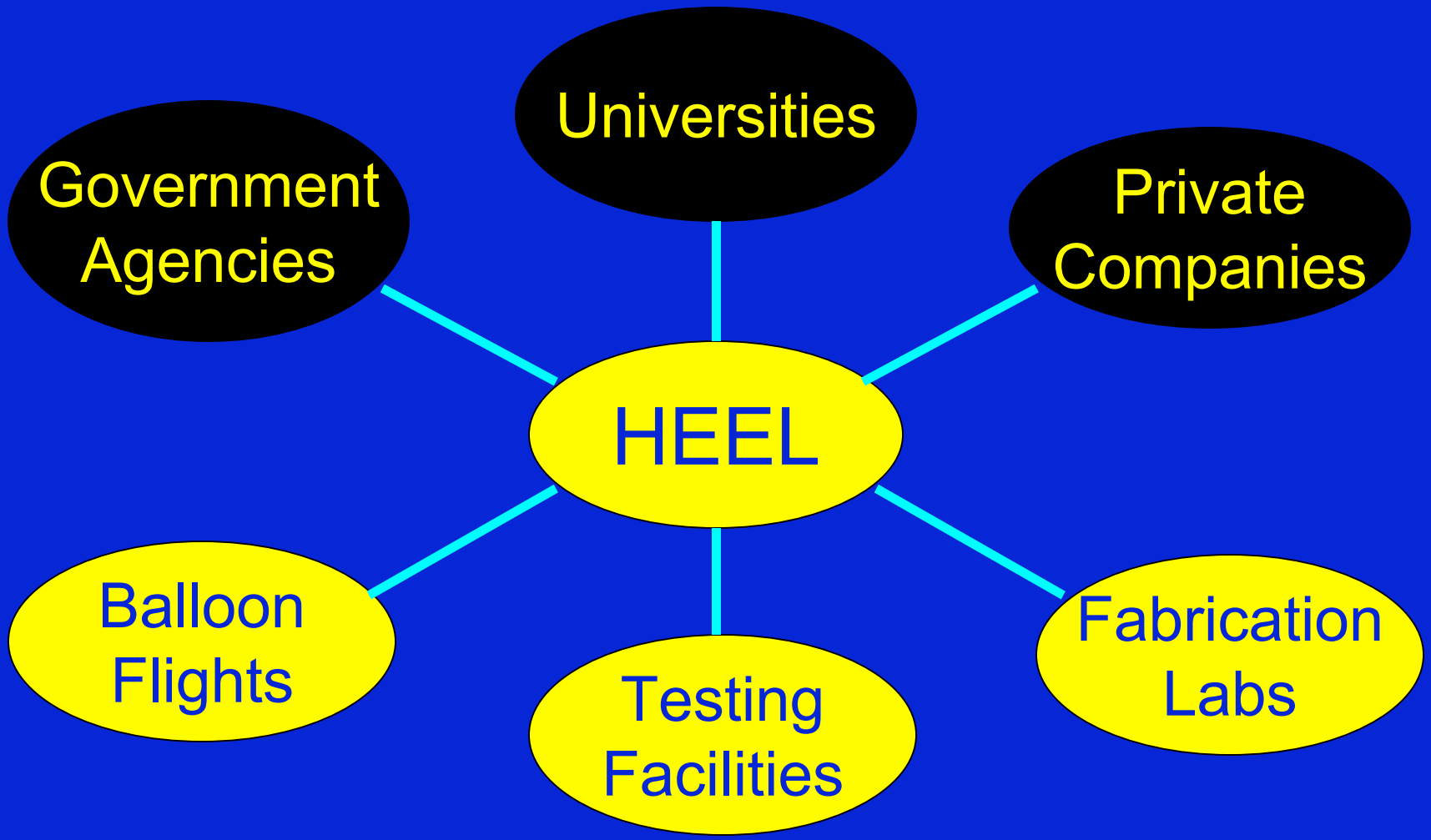
  Assistant Professor of Electrical Engineering
- Dr. Shawn Decker, Director

  Center for Accelerated Applications at the Nanoscale (CAAN)
- Dr. Brian Hemmelman

  Associate Professor of Electrical Engineering
- Dr. Nian Zhang

  Assistant Professor of Electrical Engineering

Organization of HEEL



Effects of Radiation on Electronics

- Computer memory (“0” or “1”) can be altered by radiation via the resulting ionization (SEU’s).
- Atoms in the material can be physically dislocated.
- Nuclei can be transformed into other isotopes that change the behavior of the material.

Purpose of Homestake Electrical Engineering Laboratory (HEEL)

- We propose to construct a prototype facility for the study of semiconductor materials and the behavior of electronics in an ultra-low radiation environment.

- We plan to construct and test radiation-hardened circuits, photovoltaics, nanotechnology, and components for quantum computers.

Questions

- Will the reduction in defects from cosmic rays yield surfaces, materials, and devices that have unique and valuable properties?

- Will said materials and devices prove beneficial not only at 4850 feet below the surface, but also on the surface and in space?

Physical Requirements

- We require a Class 100 clean room at the 4850 foot level.
- This clean room will be ~150 cubic meters in volume.
- An adjoining room for device characterization will require ~ 500 square feet of space.
- Estimate: 4-6 months for construction.

Clean rooms

- If devices built in Class 100 clean rooms show promise, we will then study effects for devices manufactured in a Class 1 clean room.
- If it is beneficial to manufacture devices in a Class 1 environment, then commercial production should be considered.
- Homestake would provide the greatest future manufacturing capacity in an ultra-low radiation environment.

SDSU Clean Room

What happens if we see nothing?

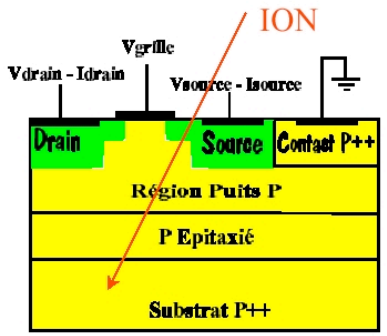
- We can still construct many different devices to be tested at Homestake.
- The research will enhance the new Ph.D. in Electrical Engineering at South Dakota State University.
- The School of Mines currently has no clean room facilities.

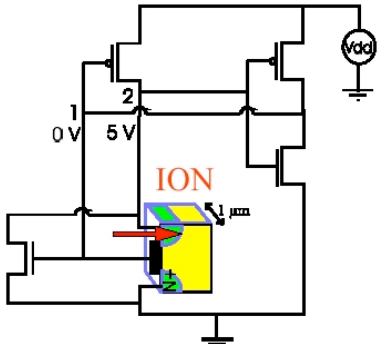
Evaluation of devices

- Comparisons need to be made between electronics built at 4850, and electronics built on the surface.
- Soft-error upsets in circuits will be studied below the surface, on the surface, and via high-altitude balloon flights.
- We expose devices to a large dose of X-rays, and simulated conditions in space.
- Materials science characterization of devices will be performed (XPS, etc.).

SEU's: Single Event Upsets or Soft Error Upsets

- Intrinsic electric fields in the device can prevent the recombination of electron-hole pairs[1].
- We request minimal space on several levels to store circuits and other equipment.
- Temperature within ± 20 °C of room temperature.

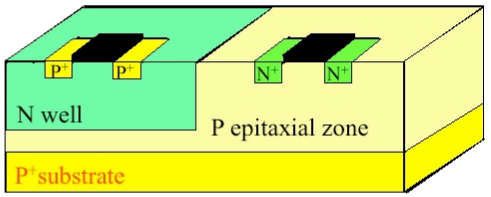


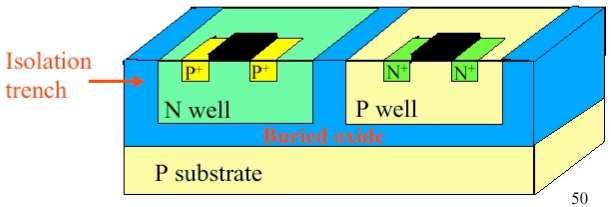


Effects in CMOS technologies

SEL Hardening

- Epitaxy
- Doping
- SOI





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[1] *Single Event Upsets in Microelectronics: Fundamental Physics and Issues*, Tang and Rodbell, MRS Bulletin, February 2003, p. 111-116.

Testing Infrastructure

- We request space at or near the surface for these components.

X-ray Machine[2]

Space Simulation Thermal Chamber[3]

[2] http://www.xtekxray.com/systems.htm#hmxst [3] http://lre.com/test2/docs/menu.htm

Synergy with other Homestake LOI

- We would use a research reactor from the study of neutron - anti-neutron oscillations to irradiate electronics.
- We could use a particle accelerator to irradiate electronics.
- We propose to irradiate our electronics via high-altitude balloon flights, and other experiments would have access to that infrastructure.
- Testing of particle physics detectors could be performed within HEEL's auspices.

High-Altitude Balloon Flights

- Expose circuits, solar cells, other technologies to cosmic rays.
- Test communication systems in the upper atmosphere.
- Astronomy and particle astrophysics.
- Meteorological studies of the upper atmosphere.
- NASA, NOAA, DOD, commercial interests

Aerial photograph by

Dakota Aerials, Yankton, SD

In summary...

- HEEL will assess the manufacturing processes of electronics in a reduced radiation environment, and pursue possible commercial interests if proven beneficial.
- HEEL will evaluate the behavior of devices we construct at Homestake.
- We anticipate synergy with many different groups.

Thank you for your “Patience”.

Image Courtesy of South Dakota Art Museum, Brookings, SD 57007

Low-Alpha Lead & the Cosmic Ray Equivalency Factor

GI Lykken, Dept. of Physics, UND,
RL Brodzinski, PNNL,
Earl Palmer, Palm Leaf Products, &
Mike Tucker, Alpha Sciences

Acknowledgements

Tim May e-mail reply to John Gieser, June 1997

Low-Alpha Lead Symposium, LAL, Feb 26, 1997

Gary Larson, Far Side Comics

Ten Best Pictures of the Year 2003

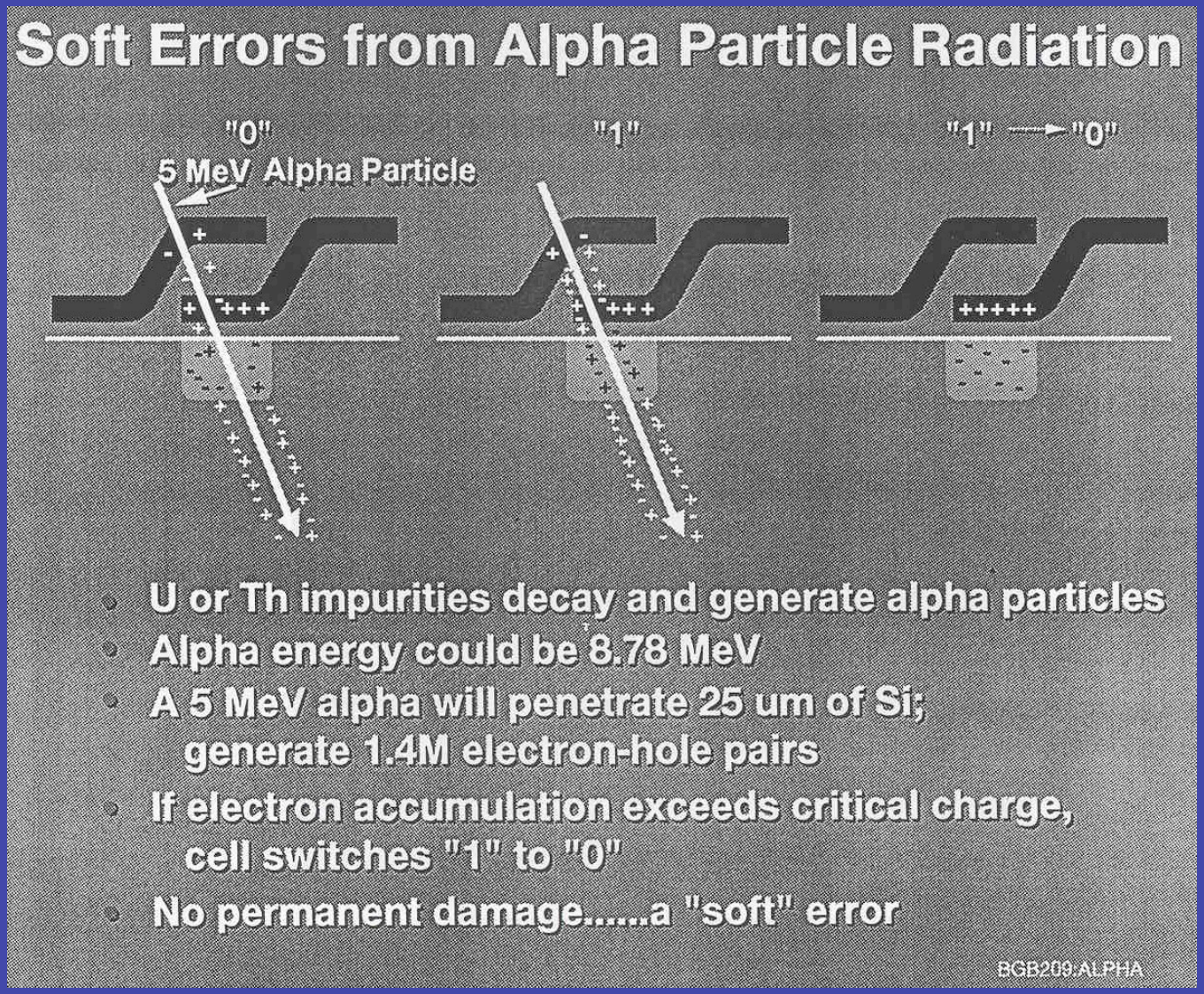
Soft Errors- Genesis

Tim May in an e-mail June 1997

"How I came to suspect low levels of uranium and/or thorium while I was sitting in an outdoor hot tub (or Jacuzzi) at my apartment complex in Sunnyvale, CA makes for a good anecdote, and a true one, of course."

"Much of what I did was never allowed to be published. But, fortunately, Intel rewarded me in various ways, which is why I've been a man of leisure (!!) since 1986."

Soft Errors



Soft errors may also be caused by cosmic rays.

Low-Level ∀ Counting

Mike Tucker-Alpha Sciences Jan 2006

"I'm midway through an unsolicited paper on a frighteningly recurring event; companies making the incorrect assumption that because they are now lead-free, they are alpha-free.''

"On the contrary, we've measured several 'solder' replacements, completely free of Pb, only to find them very active (10x higher than comparable Pb), some on the order of 0.10 _/cm^2/hr. ''

"It would be of great interest to see what effect, if any, cosmic rays might have upon the alpha activity of a sample…"

Low-Level ∀ Counting

- **Mike Tucker-Alpha Sciences Jan 2006**
- ***"The last Model 1950 to go out the door to a customer (shipped Dec. 23, 2005) was showing a background of 1.733 counts/hr."***
- ***"Over the 1000 sq cm area of the window, that's 0.0017 a/cm ^{2}/hr background."***
- ***"Over a period of 40 hours, the Lower Limit of Detection would be 0.0009, and down to 0.00057 after 100 hours."***

Low-Level (Counting

Ron Brodzinski, PNNL January 2006

"In order to achieve these levels of sensitivity, it is necessary to utilize construction materials with unprecedented low-levels of radiological impurities; many orders of magnitude lower than the equilibrium levels of radioactivity maintained in most materials by cosmic-ray activation."

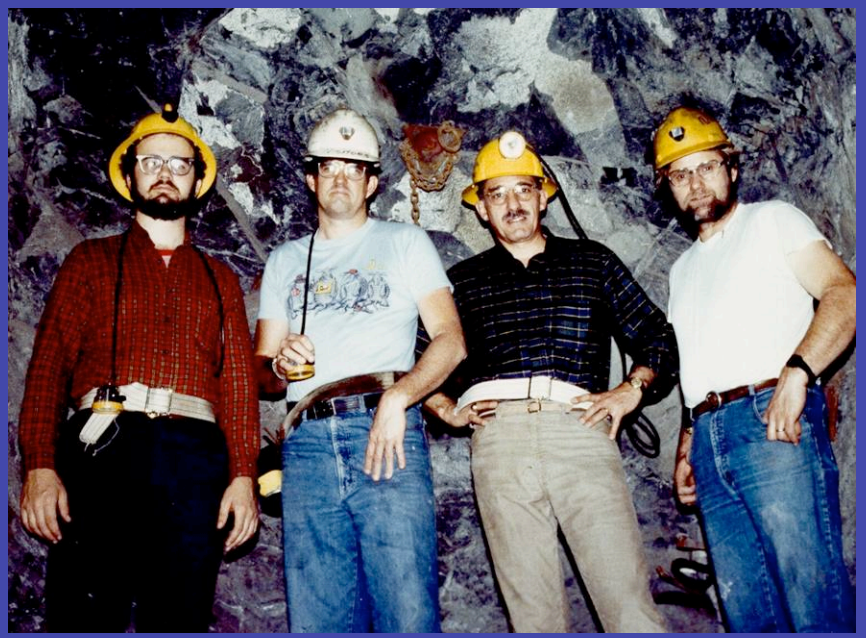
"There is a point, however, where the level of cosmic-ray interactions in these materials, will render further efforts to reduce radioactive impurities in these materials meaningless. At that cosmic-ray-equivalency level, further efforts and expense to reduce radiological impurities in component materials will be pointless, except for those instances of deep underground deployments."

"These cosmic-ray equivalency factors have never been measured for any material."

More on Low-Level (Counting

- **Ron Brodzinski, PNL**
  January 2006

"The 4 musketeers was taken at the start of our experiments in Homestake at the 4850-foot level circa 1981."



Proposed Experiment

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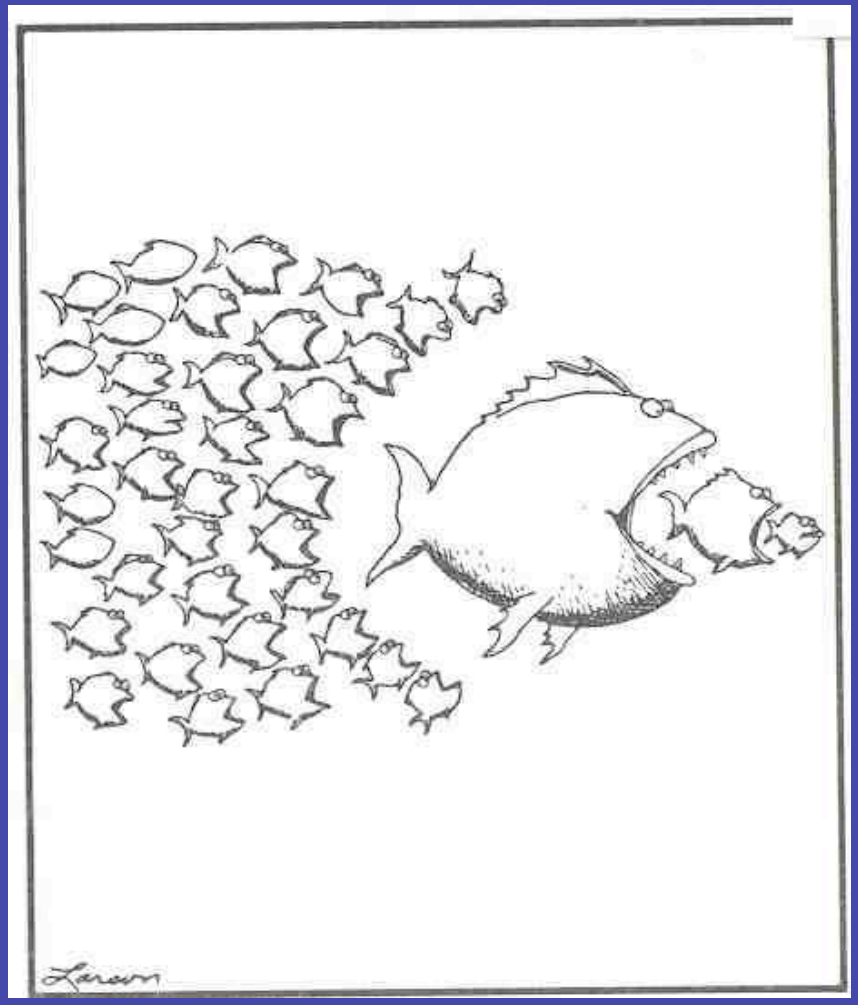
Ron L. Brodzinski, Battelle Pacific Northwest Laboratory, ron.brodzinski@pnl.gov,
Earl Palmer, Palm Leaf Products, Inc., epalmer2@verizon.net, and
Mike Tucker, Alpha Sciences, Inc., ike@alphacounting.com.

1. *"We propose to determine the effect of cosmic rays by measuring radiation from materials used in semiconductor memories in the presence of cosmic rays (at the surface of a deep mine) and in the absence of cosmic rays (deep underground)."*
2. *"A background counting laboratory (≈15m^3) at ground level and a background counting laboratory (again ≈15m^3)at the 4850-ft level are requested."*
3. *"Counting periods of up to three weeks at each level are anticipated beginning in June, 2007. "*
4. *"Minimal 120 V 60 Hz power (≈ 2 kW) to operate the detector and data acquisition equipment is anticipated."*
5. *"Access to the internet to remotely operate data acquisition equipment is required."*

Thank you for your kind attention!



Could the cosmic-ray equivalency factor be an enigma?

Nu-light for DUSEL